Self-organisation of morphology and sediment transport in alluvial rivers

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The coupling of sediment transport with the flow that drives it shapes the bed of alluvial rivers. The channel steers the flow, which in turns deforms the bed through erosion and sedimentation. To investigate this process, we produce a small river in a laboratory experiment by pouring a viscous fluid on a layer of plastic sediment. This laminar river gradually reaches its equilibrium shape. In the absence of sediment transport, the combination of gravity and flow-induced stress maintains the bed surface at the threshold of motion (Seizilles et al., 2013). If we impose a sediment discharge, the river widens and shallows to accommodate this input. Particle tracking reveals that the grains entrained by the flow behave as random walkers. Accordingly, they diffuse towards the less active areas of the bed (Seizilles et al., 2014). The river then adjusts its shape to maintain the balance between this diffusive flux, which pushes the grains towards the banks, and gravity, which pulls them towards the center of the channel. This dynamical equilibrium results in a peculiar Boltzmann distribution, in which the local sediment flux decreases exponentially with the elevation of the bed (Abramian et al., 2019). As the sediment discharge increases, the channel gets wider and shallower. Eventually, it destabilizes into multiple channels. A linear stability analysis suggests that it is diffusion that causes this instability, which could explain the formation of braided rivers (Abramian, Devauchelle, and Lajeunesse, 2019).

References: